Subject

A BOOSTER MONITOR AND CONTROL SYSTEM

I. Abstract

A computer based monitor and control system for the booster is described in this memo. The purpose of this system is to provide the necessary interface between the machine operator and the booster. It will accept input from him and make appropriate modifications to the present operating parameters. It will also display to him reduced forms of data gathered from the machine. As seen from booster equipment, such as the booster rf system, the orbit correction magnet power supplies, etc., this system will provide the necessary timing and control commands.

II. The Problem

To operate the booster efficiently, a system must be provided that will make man-machine communications easy and efficient. Because of the physical extent of the booster and its associated equipment, it is desirable to time share cabling for economic reasons. The specific nature of this time multiplex system in the booster is somewhat different than that described by Dr. Littauer for the Main Ring (FN-51). The prime difference in application here is that the physical arrangement of the buildings associated with the booster suggests a tree-type distribution system as opposed to the more linear system used at Cornell and suggested for the Main Ring. A typical cable routing is shown in Figure 1 showing the branch points. Logically, there will be a multiplex point at each magnet and one for each long straight section (the other straights will share a point with their upstream magnet). Physically, the equipment in the ring will be packaged in one unit per period to simplify power, supplies, cabinetry, etc. There will be a multiplex point for each device in the gallery (e.g., d.c. power supply).

There are five general types of signals that will be handled by this time multiplex system. These are:

1. Timing signals to activate a device.

2. Digital values that are transmitted to a device at specific times throughout the cycle; e.g., frequency commands to the rf system. In some cases these words will be interpreted by the receiving device as control commands.

3. Digital data to devices where timing is not critical; e.g., current magnitude in d.c. correction magnets.

4. Analog signals returning from the machine; e.g., induction electrode signal.

5. Equipment status signals from booster equipment. These different types of signals and the technique for handling them is discussed in the following sections.

III. Timing Pulses

The required accuracy for timing pulses was discussed in Engineering Note EN-107, A Booster Timing System. The system described here is computer based and can use computer's mathematical ability to change digital values from the operator into appropriate form for equipment. This removes the restriction of having a B clock that steps in decimal related B steps.

The B clock will have a resolution of 1/16 gauss and a maximum frequency of 5.85 MHz. This requires 18 bits for value plus one for the sign of B. Normally, the lower 14 bits will be compared. At about 8 times the upper 5 bits will be compared to prevent getting lost.

The 16 bit computer word, plus one bit for parity, will be transmitted in parallel around the booster complex. The two high bits will be used to identify the word. The next nine bits will provide an address which will be identified by the receiving unit. The time at which the word is transmitted from the computer will be synchronized by the B. Clock. When the receiving device detects its nine bit address, it interprets the time to be its time for status change. There are 512 possible addresses. The lower five bits of the word will be used to address specific device at that location so a given 16 bit word represents location and a specific action at that location. For instance, triggering an orbit bump power supply or commanding an analog gate to connect a shunt to the analog signal bus. The layout of these words is shown in the table.

IV. Synchronized Data

Data will be transferred from the computer to device along the same 16 bit parallel distribution system. First, a 14 bit address will be transmitted as in the case of timing pulses, and this will be immediately followed by the 14 bit data word. The address will enable the particular gate at the proper location to transfer the data to the local register. An example of an appropriate receiver for this would be a D to A converter to drive the rf system frequency program. Here the local register would be connected to the D-A converter. Another example would be a 14 bit status word which would be interpreted by the receiving word on a bit-by-bit basis. One bit would be used to turn on the a.c. power, one the d.c. power, one to initiate current run up, etc.

V. Asynchronous Data

Asynchronous data will be transmitted in the same way as the synchronous data. It will use the same set of signal leads and the same addressing scheme.

When synchronized data is transmitted, it is under the control of the B clock; whereas the asynchronous data is transmitted during blocks of time providing for that data under the control of the computer. These blocks of time will be provided when the beam is not in the machine; that is, when B is negative.

VI. Analog Data

There will be one signal path around the booster complex for analog signals to be returned to the computer. Analog signals that vary slowly with time, such as magnet shunt readings, magnet temperatures, etc. will be switched onto a bus, one at a time, using the command system described in Section III.

There also will be a fast system (20 MHz) which will provide five signal paths back to the central control room. The sources that are connected to these five lines will be selected also through the addressing system described in Section III. Signals that will be on these cables will be induction electrode signals, pulse magnet current, etc. These five lines will be available in the control room for oscilloscope operation. There will be six A-D converters to convert these analog signals coming back from the machine.

VII. Closed Loops

Electronic systems, such as rf amplifier and d.c. power supplies, will have their own local analog closed loops. There will be some closed loops that will include the control computer. An example of this would be the systems to control the radial position of the beam. A table of values will be generated to command the frequency of the accelerating voltage. Measurements would then be made on the radial position of the beam using the A to D system described above. The table that is used for the frequency program will be updated to bring the beam to the desired radius program. This is an activity that the computer would accomplish on a time-share basis with other activities; that is, it would correct the frequency program for a short period of time, say one minute, and then go to other jobs and return to checking the frequency program, say once every ten minutes.

VIII. Computer

The use of a computer in this system provides the operator with a greater flexibility and ease of operation than could be achieved with any hard-wired system. The computer also reduces the engineering effort required at the laboratory to realize an adequate control system. By using a 16 bit parallel distribution system, the computer can be used to organize and distribute signals with a minimum of external equipment.

The computer will be able to monitor devices and display the information to the operator in forms that will be easily digested by him. The computer will be able to help diagnose difficulties as they arise and aid the operator in correcting faults. The computer can also provide operational records.

There will be a typewriter station in each gallery to allow personnel in the galleries to operate the devices they are working on and to obtain general machine status.

IX. Maintenance

Computer based maintenance programs have been initiated at other accelerators with great success. This type of work can be included as a background job for the control computer. This would be a card based system with a card per job generated by the computer. These cards would be given to maintenance people who would return them when they have completed the task. The computer would keep track of the status of the maintenance program and produce maintenance records.

X. Central Control

This system communicates with a central control system by direct parallel transfer. The central system will be able to initiate any programs in the booster repetoire. Also, it can receive any data the booster system can gather. This data can be reduced in the booster computer.

XI. Examples

An example of the application of this system to a piece of equipment would be helpful at this point. The example chosen is a d.c. power supply for powering a beam transport magnet. The power supply would have local digital controls that would allow it to be energized and controlled independent of the central control system. The multiplex station would provide a set of relay enclosures (up to 14) which would control the a.c. contactor, d.c. on-off controls, etc. If this current was to be regulated to 0.1%, there would be a 10 bit register and D to A converter as part of the multiplex station to provide a command to the power supply. The shunt for reading the current in the power supply would be connected to its analog switch for the analog bus. The power supply would provide up to 14 contact enclosures to indicate the status of substance within it. For instance, control power on, a.c. power on, water flow - o.k., air flow - o.k., magnet water - o.k., etc. The equipment safety interlocks would be hard-wired but their status would be indicated by these contact enclosures. This status word would be transmitted by the central control system back to the central computer. A closed loop might be generated around this power supply by having the control system sample a beam position downstream from this magnet. This position would be changed by updating the digital command to the power supply.

Another example is ring magnet interlocks. Water flow and temperature interlocks can be summed at each magnet and one hard-wired interlock path would sum these for the power supply. When a fault occurred, the power supply would shut down independent of the control system. The control system would then scan the magnets to determine the location of the fault and display the location and nature of the fault to the operator.

XII. Schedule and Manpower

This system will be useful during equipment development time to provide the equipment drive signals to people who ultimately will use those signals. This control system would similate the machine and provide control signals as required during equipment development. The schedule would be as follows:

1. Specifications finished by September 15, 1968.
2. Contract for computer by November 1, 1968.
3. The computer delivered and installed in the Booster Building by July 1, 1969.
4. The computer will be running on a time-shared multi-programming basis by January 1, 1970. By that time test signals will be distributed to any equipment that requires them.
5. The system would be complete by July 1, 1970.

The manpower required to utilize this system on that schedule would be one engineer, one programmer, and four technicians.

A detailed schedule is shown in Figure 2.

FIGURE 1

CABLE ROUTING

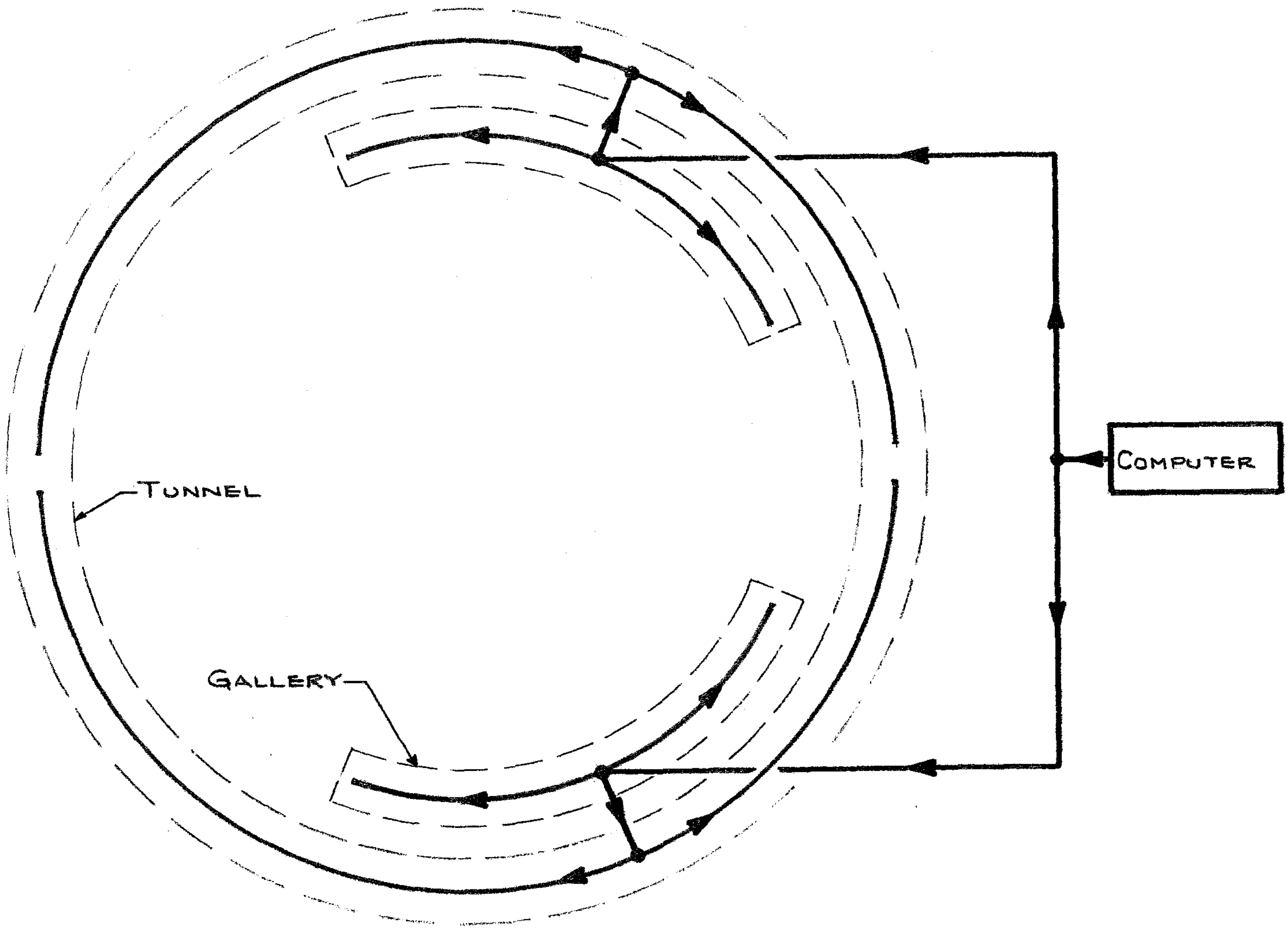
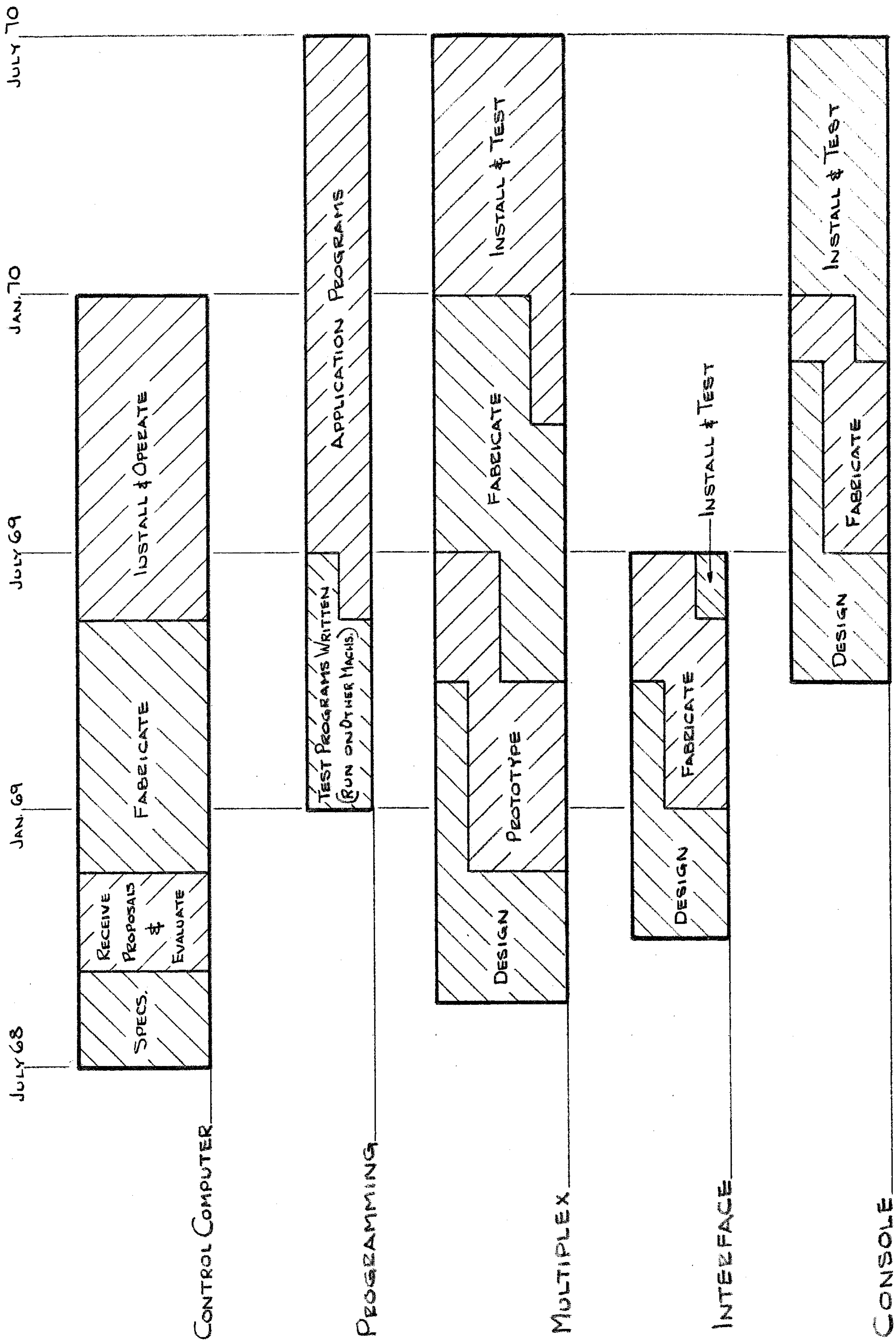


FIGURE 2

SCHEDULE



WORD STRUCTURE